

PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in or relating to Turbines, Compressors and like Fluid Flow Apparatus

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, a British company of 25, Green Street, London, W.1, do hereby declare the nature of this invention to be as follows:—

This invention relates to the manufacture of blades for turbines, compressors and similarly bladed fluid flow machines, and also has application to guide blades for use in fluid flow systems, for example, to the individual blades of a cascade in a pipe bend.

The profiles of such blades are arrived at from a consideration of their functions of deriving lift from, or directing, the fluid flow and of reducing as far as possible their resistance to the flow, and in many instances the performance of a blade is highly critical with respect to its profile in general, and more especially to the part of the profile in the region of the leading and trailing edges of the blade.

In manufacturing such blades the method commonly adopted is to form the material approximately to the desired shape by forging, casting, or partly machining a blank, and to obtain the finished profile by a draw filing or similar operation using a form gauge for reference, the latter step involving considerable time and cost. Moreover, the profile of the leading and trailing edges of a blade are in general, of a small radius of curvature compared with the remainder of the profile and are very difficult to form correctly by this method since small departures in shape from that of a form gauge are not easily detected; this difficulty is obviously enhanced in the case of blades of small size.

Furthermore, blades of the kind under consideration do not, in general, lend themselves to the formation of their leading edge by a rotating shaped cutter or grindstone for the following reasons. Firstly the blades, with their profiles partly formed, must be supported and aligned accurately with the cutting tool

so that the latter is able to make a correct finishing cut; the difficulties involved in setting up each blade outweigh, to a great extent, the advantages of the method. Secondly, due to the common general form of the blades, that is with thickness small compared with length, they may deflect under pressure from the cutting tool, by an amount sufficient to produce a badly malformed section. A third disadvantage lies in the fact that, in many cases, the blade section varies throughout its length, in respect of size, shape and angle of inclination to the fluid flow, and a rotating cutter of a shape suitable for forming one section of the blade may undercut at other sections.

The object therefore of the present invention is to provide a method whereby the leading edges of blades may be formed quickly to within desired limits of accuracy, and the invention takes advantage of the fact that the remainder of the profile of a blade may be, and indeed commonly is, formed with the desired accuracy before the leading and trailing edges are formed.

The invention proposes that a blade of the kind referred to shall have either its leading or trailing edge, or both, formed to finished size by a swaging or similar action of a tool of appropriate shape causing plastic flow in the material of the blade.

In the preferred form of the invention it is contemplated that the edge of a blade be shaped by contact with a roller which rotates with translation along the blade edge and has a groove formed in its periphery such that the radial cross-section of the roller groove at any given circumferential point corresponds wholly or partly with the desired cross-section at a point on the blade profile with which the roller groove is momentarily in mutual contact during motion of the roller with respect to the blade.

Thus a partly formed blade may be sup-

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ported with its leading edge substantially normal to the axis of a roller having an appropriately shaped peripheral groove, so that the roller, when forced against the blade edge and passed one or more times from end to end, will reduce the blade edge to the desired finished size by causing plastic flow in the blade material.

The invention further proposes that the forming tool be free to move in a direction normal to the blade edge. Thus, in the preferred embodiment of the invention, the roller is so arranged as to be able to move axially; by this means the necessity for a high degree of accuracy in setting up the blade with respect to the roller is eliminated provided that the blade profile, excluding, of course, the leading and/or trailing edge, is previously finished, since the axially floating roller may be so arranged as to position itself correctly by contact between the sides of the groove in the roller with the finished profile adjacent to the edge of the blade; similarly, should the blade deflect under pressure from the roller, the latter is enabled to follow up the blade and maintain correct relationship with respect thereto.

In order that the necessity for, and the problems involved in obtaining, the correct profile at the edge of a blade may be more clearly understood, they will now be described, as they apply more particularly to the leading edge, with reference to the accompanying drawings, which illustrate, in part or in whole, various cross-sections of a blade typical of the kind under consideration.

In Figure 1 the full line represents a blade section designed for operation in a fluid stream flowing in the direction of the arrow A; it will be observed that the leading edge of the section points directly upstream so that the flow of fluid round the section is as smooth as possible; the broken lines indicate errors in the blade section such as might occur in its manufacture. It will be seen that small errors in the profile of the leading edge may result in a section having an inlet angle different to that intended, with consequent disturbance in the fluid stream over the blade, whereas an error of similar magnitude in the portion of the blade profile between the blade edges has less serious results.

Figure 2 shows on a reduced scale a section through the blade at a stage of manufacture prior to the formation of its leading edge: the blade has been machined from a bar of material of cross-section 1 by a method, commonly used, in which the profile 2 is machined to finish size on each of its sides 3 and 4 where the radius

of curvature is large, leaving a quantity of surplus material at the leading edge, as shown enlarged in Figure 3 in which the surplus material is represented by a broken line in relation to the full line of the desired section. The surplus material may be reduced by making a cut tangential to the leading edge, as illustrated at 5 in Figure 4, leaving two small triangular portions 6 and 7 to be blended away to form the correct leading edge profile. As has already been mentioned, the removal of these portions by draw filing or similar means leads to inaccuracies in the profile.

An arrangement for finishing the blade by using a rotary cutting tool of suitable shape is illustrated in Figure 5. With reference to the Figure, a grindstone wheel 8, having a shaped peripheral groove 9 and rotating about an axis 10, is moved, in relation to the blade section 11, in the direction of the arrow B which conforms with the inlet angle of the blade. The blade section 11 can be correctly finished only if the centre line 12 of the grindstone groove 9 coincides with the centre line 13 of the leading edge of the section; if, as in Figure 5, they are misaligned, the section produced will be as illustrated by the full line in Figure 6 as compared with the broken line of the correct section. A similar defect may occur due to the flexing of the blade (in the direction of the arrows C and D in Figure 5), under lateral pressure exerted by the tool. It is, therefore, apparent that the practical difficulties of this method render it unsuitable for the production of blades on a large scale.

However, by using a method of manufacture according to the invention, the disadvantages of the methods outlined in the foregoing may be avoided, as will be seen from the following description of the preferred form of the invention.

Figure 7 of the accompanying drawings shows an arrangement for use in the manufacture of a blade of constant section throughout its length. With reference to the Figure, the blade 14 is partly formed by the method described with reference to Figures 2, 3 and 4, leaving portions 15 and 16 of the bar from which the blade is formed at each end to facilitate the various operations; the blade root portion 17 is also partly formed at this stage. The blade is mounted in a tilted position so that its leading edge is uppermost and is in a horizontal plane, and so that its inlet angle coincides with the vertical, as illustrated in sectional elevation in Figure 8. A carrier arm 18 is disposed above the blade and is adapted so as to be capable of reciprocation in a

direction parallel to the leading edge of the blade, as indicated by the arrow E, and also of a small vertical displacement; the carrier arm provides a journal 19 for a roller 20. The roller has a groove 21 formed in its periphery the radial cross-section of which conforms with the desired leading edge profile of the blade for a part of the depth of the groove. The material of the roller 20 is so selected as to be relatively hard compared with that of the blade 14 so that, when the roller is brought into vertical contact with the blade edge under pressure, as in Figures 7 and 8, and the carrier 18 reciprocated in the direction of the arrow E between the positions shown by the full and broken lines respectively, the surplus material on the leading edge of the blade is evenly distributed, and the profile correctly shaped. The resultant effects are firstly that the blade material is locally work-hardened which is obviously an advantage, and secondly that the chord of the blade is increased by a small amount; in practice the increase is found to lie within the limits of accuracy necessary for the chordal dimension of the blade, and can therefore, be disregarded. The movement of the carrier arm 18 in the vertical direction is limited to the desired amount by suitable stops. The roller 20 may rotate freely or may be driven at any desired speed.

In order to ensure correct alignment of the roller 20 with respect to the leading edge of the blade, the groove 21 is made deeper than is actually required to form the blade edge, so that the radially outermost parts of the sides of the groove make contact with the previously finished portions of the blade profile; by permitting the roller some freedom of movement in the direction of its axis, its correct alignment with the blade is ensured and allowance is thereby made for small machining inaccuracies and flexing in the blade.

After the edge rolling operation the blade is completed by cutting away the end portions 15 and 16 (as indicated by the broken lines 22 and 23).

Although the foregoing description has confined itself to the case of a blade performed by machining, it is apparent that the method is, for the greater part, applicable to blades produced by other means, for example, by forging or casting, followed by an operation preparing them for the formation of their leading edges.

The method may, with slight modification, be applied to a blade whose section varies throughout its length. Figure 9 illustrates a blade 24 of tapering section the leading edge of which is to be formed.

As before, the blade having been brought to the requisite stage of manufacture, a grooved roller 25 is passed over the leading edge, reciprocating between the positions shown in full line and broken line respectively. In order to provide for the varying blade section, however, the radial cross-section of the roller groove varies, in this case, at varying points on the circumference, and the roller rotates only by an amount, and at a speed, appropriate for a running contact between the groove and the blade edge. The bottom of the groove is concentric with the axis of the roller, as represented by the broken line 26, so that the blade may be mounted with its leading edge parallel to the path of reciprocation of the roller, whilst the roller periphery 27 may be of any form depending on the varying depth of the groove; in the present case, for convenience, the periphery 27 forms part of a circle eccentric to the roller axis. The length of the groove around the roller periphery will be approximately the same as the length of the blade; a gap 28 is provided in the periphery between the ends of the groove to clear the blade root when the roller is at the root end of a blade. In order to ensure that the blade and roller are kept in their correct relative positions, the roller spindle may carry a pinion, having a pitch diameter the same as the mean diameter of the roller groove, engaging a rack which is fixed with respect to the blade. In this, as in the previously described form, the roller may be permitted some freedom of lateral movement, and in either case the reciprocal movement may, of course, be applied to the blade itself instead of to the roller.

Although the method described in the previous paragraph is intended primarily for use in manufacturing blades of varying section, it is contemplated that it will also have application to blades of varying inlet angle. Provided that the variation in the inlet angle were small, the blade could be mounted with its mean inlet angle vertical and its leading edge, as before, parallel to the roller path. The variation in the inlet angle could then be accommodated by the changing section of the groove. If, however, the variation were large, this method would be impracticable due to the fact that the amount of the leading edge profile to which the groove conformed at one section would be limited by the inlet angles of other sections. In forming such a blade, therefore, the method would require modification in that the blade would have to describe a rotational movement, relative to the

roller, about a longitudinal axis simultaneously as the roller reciprocated over it, so that the inlet angle of any given section would be substantially vertical at the moment when the roller passed. The rotational axis of the blade would preferably pass through a point in each section close to or near the centre of curvature of the leading edge, and the roller might require more lateral movement than in the case of a fixed blade. The rotational movement of the blade would, of course, be geared to and synchronised with the roller reciprocating mechanism.

In the first of the embodiments described, the groove in the roller may be formed by turning or a similar operation; for the roller of the other embodiments, however, this is not possible. A method of forming the roller groove suitable for all cases is illustrated in Figures 10 and 11 of the accompanying drawings and will now be described with reference thereto. One edge 29 of a piece of steel 30 is worked by hand to the form of the blade edge desired (in this case of tapered section), and is hardened to form a master pattern. It is then mounted on a reciprocable table over which, mounted on a suitable spindle, is the roller 31, in which is to be machined the leading edge form; the roller 31 is geared to the table in the manner described with reference

to Figure 9, so that the roller 31 and the master pattern 30 are maintained in their correct relationship. As steady pressure is applied in the downward direction to the roller, the blade edge is reciprocated with respect thereto thus pressing the form from the hardened master pattern 30 into the roller which at this stage is of soft metal. The roller is then hardened and finished, when it is ready for use. When large numbers of similar blades are required, several rollers may be made from the same master pattern.

When producing the rollers for manufacturing blades of varying inlet angles, the method would be modified; in the case where the variation is small the master pattern would be mounted with its mean inlet angle vertical, and when the variation is large the master pattern would be subjected to the same rotational movement as is ultimately to be applied to the blades whilst under the roller.

Although the embodiments of the invention described have dealt specifically with the case of the formation of the leading edge of a blade, it is apparent that they are in many respects equally suitable for forming the trailing edges of blades.

Dated this 6th day of October, 1948.
J. R. TOD,

Chartered Patent Agent,
Agent for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Turbines, Compressors and like Fluid Flow Apparatus

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, a British company of 25, Green Street, London, W.1, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the manufacture of blades for turbines, compressors and similarly bladed fluid flow machines, and also has application to guide blades for use in fluid flow systems, for example, to the individual blades of a cascade in a pipe bend.

The profiles of such blades are arrived at from a consideration of their functions of deriving lift from, or directing, the fluid flow, and of reducing as far as possible their resistance to the flow, and in many instances the performance of a blade is highly critical with respect to its profile in general, and more especially to the part of the profile in the region of the leading and trailing edges of the blade.

In manufacturing such blades the

method commonly adopted is to form the material approximately to the desired shape by forging, casting, or partly machining a blank, and to obtain the finished profile by a draw filing or similar operation using a form gauge for reference; the latter step involving considerable time and cost. Moreover, the profile of the leading and trailing edges of a blade are, in general, of a small radius of curvature compared with the remainder of the profile and are very difficult to form correctly by this method since small departures in shape from that of a form gauge are not easily detected; this difficulty is obviously enhanced in the case of blades of a small size.

Furthermore, blades of the kind under consideration do not, in general, lend themselves to the formation of their leading edge by a rotating shaped cutter or grindstone for the following reasons. Firstly the blades, with their profiles partly formed, must be supported and aligned accurately with the cutting tool so that the latter is able to make a correct

finishing cut; the difficulties involved in setting up each blade outweigh, to a great extent, the advantages of the method, secondly, due to the common general form of the blades, that is with thickness small compared with length, they may deflect under pressure from the cutting tool, by an amount sufficient to produce a badly malformed section. A third disadvantage lies in the fact that, in many cases, the blade section varies throughout its length, in respect of size, shape and angle of inclination to the fluid flow, and a rotating cutter of a shape suitable for forming one section of the blade may undercut at other sections.

The object therefore of the present invention is to provide a method whereby the leading edges of blades may be formed quickly to within desired limits of accuracy, and the invention takes advantage of the fact that the remainder of the profile of a blade may be, and indeed commonly is, formed with the desired accuracy before the leading and trailing edges are formed.

The invention proposes a method of manufacturing a blade of the kind referred to having a profile an edge of which, being itself of small radius of curvature, is bounded by portions of relatively large radius of curvature, characterised in that said edge of the profile is formed by the swaging action of a tool having a groove of appropriate shape which embraces said edge.

The invention further proposes that the above method comprises the steps of shaping the portions of the blade profile of large radius of curvature substantially to the desired profile, and subsequently forming the edge of the profile, characterised in that the deformation produced by the action of said tool is effectively controlled by contact between said groove and the portions of the blade profile of large radius of curvature.

In the preferred form of the invention it is contemplated that the edge of a blade be shaped by contact with a roller which rotates with translation along the blade edge and has a groove formed in its periphery such that the radial cross-section of the roller groove at any given circumferential point corresponds wholly or partly with the desired cross-section at a point on the blade profile with which the roller groove is momentarily in mutual contact during motion of the roller with respect to the blade.

Thus a partly formed blade may be supported with its leading edge, substantially normal to the axis of a roller having an appropriately shaped peripheral groove, so that the roller, when forced

against the blade edge and passed one or more times from end to end, will reduce the blade edge to the desired finished size by causing plastic flow in the blade material.

The invention further proposes that the forming tool to be free to move in a direction normal to the blade edge. Thus, in the preferred embodiment of the invention, the roller is so arranged as to be able to move axially; by this means the necessity for a high degree of accuracy in setting up the blade with respect to the roller is eliminated provided that the blade profile, excluding, of course, the leading and/or trailing edge, is previously finished, since the axially floating roller may be so arranged as to position itself correctly by contact between the sides of the groove in the roller with the finished profile adjacent to the edge of the blade; similarly, should the blade deflect under pressure from the roller, the latter is enabled to follow up the blade and maintain correct relationship with respect thereto.

In order that the necessity for, and the problems involved in obtaining, the correct profile at the edge of a blade may be more clearly understood, they will now be described, as they apply more particularly to the leading edge, with reference to the drawing accompanying the provisional specification which illustrate, in part or in whole, various cross-sections of a blade typical of the kind under consideration.

In Figure 1 the full line represents a blade section designed for operation in a fluid stream flowing in the direction of the arrow A; it will be observed that the leading edge of the section points directly upstream so that the flow of fluid round the section is as smooth as possible; the broken lines indicate errors in the blade section such as might occur in its manufacture. It will be seen that small errors in the profile of the leading edge may result in a section having an inlet angle different to that intended, with consequent disturbance in the fluid stream over the blade, whereas an error of similar magnitude in the portion of the blade profile between the blade edges has less serious results.

Figure 2 shows on a reduced scale a section through the blade at a stage of manufacture prior to the formation of its leading edge; the blade has been machined from a bar of material of cross-section 1 by a method, commonly used, in which the profile 2 is machined to finish size on each of its sides 3 and 4 where the radius of curvature is large, leaving a quantity of surplus material

at the leading edge, as shown enlarged in Figure 3 in which the surplus material is represented by a broken line in relation to the full line of the desired section. The surplus material may be reduced by making a cut tangential to the leading edge, as illustrated at 5 in Figure 4, leaving two small triangular portions 6 and 7 to be blended away to form the correct leading edge profile. As has already been mentioned, the removal of these portions by draw filing or similar means leads to inaccuracies in the profile.

An arrangement for finishing the blade by using a rotary cutting tool of suitable shape is illustrated in Figure 5. With reference to the figure, a grindstone wheel 8, having a shaped peripheral groove 9 and rotating about an axis 10, is moved, in relation to the blade section 11, in the direction of the arrow B which conforms with the inlet angle of the blade. The blade section 11 can be correctly finished only if the centre line 12 of the grindstone groove 9 coincides with the centre line 13 of the leading edge of the section; if, as in Figure 5, they are misaligned, the section produced will be as illustrated by the full line in Figure 6 as compared with the broken line of the correct section. A similar defect may occur due to the flexing of the blade (in the direction of the arrows C and D in Figure 5), under lateral pressure exerted by the tool. It is, therefore, apparent that the practical difficulties of this method render it unsuitable for the production of blades on a large scale.

However, by using a method of manufacture according to the invention, the disadvantages of the methods outlined in the foregoing may be avoided, as will be seen from the following description of the preferred form of the invention.

Figure 7 of the drawings shows an arrangement for use in the manufacture of a blade of constant section throughout its length. With reference to the figure, the blade 14 is partly formed by the method described with reference to Figures 2, 3 and 4, leaving portions 15 and 16 of the bar from which the blade is formed at each end to facilitate the various operations; the blade root portion 17 is also partly formed at this stage. The blade is mounted in a tilted position so that its leading edge is uppermost and is in a horizontal plane and so that its inlet angle coincides with the vertical, as illustrated in sectional elevation in Figure 8. A carrier arm 18 is disposed above the blade and is adapted so as to be capable of reciprocation in a direction parallel to the leading edge of the blade, as indicated by the arrow E, and also of a small

vertical displacement; the carrier arm provides a journal 19 for a roller 20. The roller has a groove 21 formed in its periphery the radial cross-section of which conforms with the desired leading edge profile of the blade for a part of the depth of the groove. The material of the roller 20 is so selected as to be relatively hard compared with that of the blade 14 so that, when the roller is brought into vertical contact with the blade edge under pressure, as in Figures 7 and 8, and the carrier 18 reciprocated in the direction of the arrow E between the positions shown by the full and broken lines respectively, the surplus material on the leading edge of the blade is evenly distributed, and the profile correctly shaped. The resultant effects are firstly that the blade material is locally work-hardened, which is obviously an advantage, and secondly that the chord of the blade is increased by a small amount; in practice the increase is found to lie within the limits of accuracy necessary for the chordal dimension of the blade, and can therefore be disregarded. The roller 20 may rotate freely or may be driven at any desired speed.

In order to ensure correct alignment of the roller 20 with respect to the leading edge of the blade, and groove 21 is made deeper than is actually required to form the blade edge, so that the radially outermost parts of the sides of the groove make contact with the previously finished portions of the blade profile; by permitting the roller some freedom of movement in the direction of its axis, its correct alignment with the blade is ensured and allowance is thereby made for small machining inaccuracies and flexing in the blade.

After the edge rolling operation the blade is completed by cutting away the end portions 15 and 16 (as indicated by the broken lines 22 and 23).

Although the foregoing description has confined itself to the case of a blade pre-formed by machining, it is apparent that the method is, for the greater part, applicable to blades produced by other means, for example, by forging or casting, followed by an operation preparing them for the formation of their leading edges.

The method, may, with slight modification, be applied to a blade whose section varies throughout its length. Figure 9 illustrates a blade 24 of tapering section the leading edge of which is to be formed. As before, the blade having been brought to the requisite stage of manufacture, a grooved roller 25 is passed over the leading edge, reciprocating between the positions shown in full line and broken line

respectively. In order to provide for the varying blade section, however, the radial cross-section of the roller groove varies, in this case, at varying points on the circumference, and the roller rotates only by an amount, and at a speed, appropriate for a running contact between the groove and the blade edge. The bottom of the groove is concentric with the axis of the roller, as represented by the broken line 26, so that the blade may be mounted with its leading edge parallel to the path of reciprocation of the roller, whilst the roller periphery 27 may be of any form depending on the varying depth of the groove; in the present case, for convenience, the periphery 27 forms part of a circle eccentric to the roller axis. The length of the groove around the roller periphery will be approximately the same as the length of the blade; a gap 28 is provided in the periphery between the ends of the groove to clear the blade root when the roller is at the root end of a blade. In order to ensure that the blade and roller are kept in their correct relative positions, the roller spindle may carry a pinion, having a pitch diameter the same as the mean diameter of the roller groove, engaging a rack which is fixed with respect of the blade. In this, as in the previously described form, the roller may be permitted some freedom of lateral movement, and in either case the reciprocal movement may, of course, be applied to the blade itself, instead of to the roller.

Although the method described in the previous paragraph is intended primarily for use in manufacturing blades of varying section, it is contemplated that it will also have application to blades of varying inlet angle. Provided that the variation in the inlet angle were small, the blade could be mounted with its means inlet angle vertical and its leading edge, as before, parallel to the roller path. The variation in the inlet angle could then be accommodated by the changing section of the groove. If, however, the variation were large, this method would be impracticable due to the fact that the amount of the leading edge profile to which the groove conformed at one section would be limited by the inlet angles of other sections. In forming such a blade, therefore, the method would require modification in that the blade would have to describe a rotational movement relative to the roller, about a longitudinal axis simultaneously as the roller reciprocated over it, so that the inlet angle of any given section would be substantially vertical at the moment when the roller passed. The rotational axis of the blade would preferably pass through

a point in each section close to or near the centre of curvature of the leading edge, and the roller might require more lateral movement than in the case of a fixed blade. The rotational movement of the blade, would, of course, be geared to and synchronised with the roller reciprocating mechanism.

In the first of the embodiments described, the groove in the roller may be formed by turning or a similar operation; for the roller of the other embodiments, however, this is not possible. A method of forming the roller groove suitable for all cases is illustrated in Figures 10 and 11 of the drawings and will now be described with reference thereto. One edge 29 of a piece of steel 30 is worked by hand to the form of the blade edge desired in this case of tapered section, and is hardened to form a master pattern. It is then mounted on a reciprocable table over which, mounted on a suitable spindle, is the roller 31, in which is to be machine the leading edge form; the roller 31 is geared to the table in the manner described with reference to Figure 9, so that the roller 31 and the master pattern 30 are maintained in their correct relationship. As steady pressure is applied in the downward direction to the roller, the blade edge is reciprocated with respect thereto thus pressing the form from the hardened master pattern 30 into the roller which at this stage is of soft metal. The roller is then hardened and finished, when it is ready for use. When large numbers of similar blades are required, several rollers may be made from the same master pattern.

When producing the rollers for manufacturing blades of varying inlet angles, the method would be modified; in the case where the variation is small the master pattern would be mounted with its mean inlet angle vertical, and when the variation is large the master pattern would be subjected to the same rotational movement as is ultimately to be applied to the blades whilst under the roller.

Although the embodiment of the invention described have dealt specifically with the case of the formation of the leading edge of a blade, it is apparent that they are in many respects equally suitable for forming the trailing edges of blades.

What we claim is:—

1. A method of manufacturing a blade of the kind referred to having a profile an edge of which, being itself of small radius of curvature, is bounded by portions of relatively large radius of curvature, characterised in that said edge of the profile is formed by the swaging action of a tool having a groove of appropriate

shape which embraces said edge.

2. A method as claimed in Claim 1, comprising the steps of shaping the portions of the blade profile of large radius of curvature substantially to the desired profile, and subsequently forming the edge of the profile, characterised in that the deformation produced by the action of said tool is effectively controlled by contact between said groove and the portions of the blade profile of large radius of curvature.

3. A method as claimed in Claim 1 or 2, characterised in that there is relative movement between the tool and a blade under manufacture both longitudinally of and rotationally about a longitudinal axis of the blade, the respective relative movements being synchronised.

4. Apparatus when used for executing the method of Claim 1 or 2 comprising means for mounting a blade under manufacture, and a swaging tool, having a groove appropriately shaped to form the blade edge, adapted for movement with respect to said blade mounting means in directions both longitudinally and laterally of the groove.

5. Apparatus when used for executing the method of Claim 3, comprising blade mounting means, a grooved roller adapted both for reciprocating movement with respect to said blade mounting means normal

to its rotational axis and so longitudinally of a mounted blade and for freedom of movement along its rotational axis with respect to said blade rotating means, means for synchronising rotation of the roller with said reciprocating movement, means for rotating said blade mounting means about an axis extending longitudinally of a mounted blade in the direction of reciprocation of the roller, and means for synchronising such rotation with the reciprocating and rotational movements of the roller.

6. A method of manufacturing blades for turbines, compressors and similarly bladed fluid flow machines substantially as hereinbefore described.

7. Apparatus for manufacturing blades for turbines, compressors and similarly bladed fluid flow machines substantially as described herein with reference to, and as illustrated in Figures 7 and 8, or Figure 9 of the drawing accompanying the provisional specification.

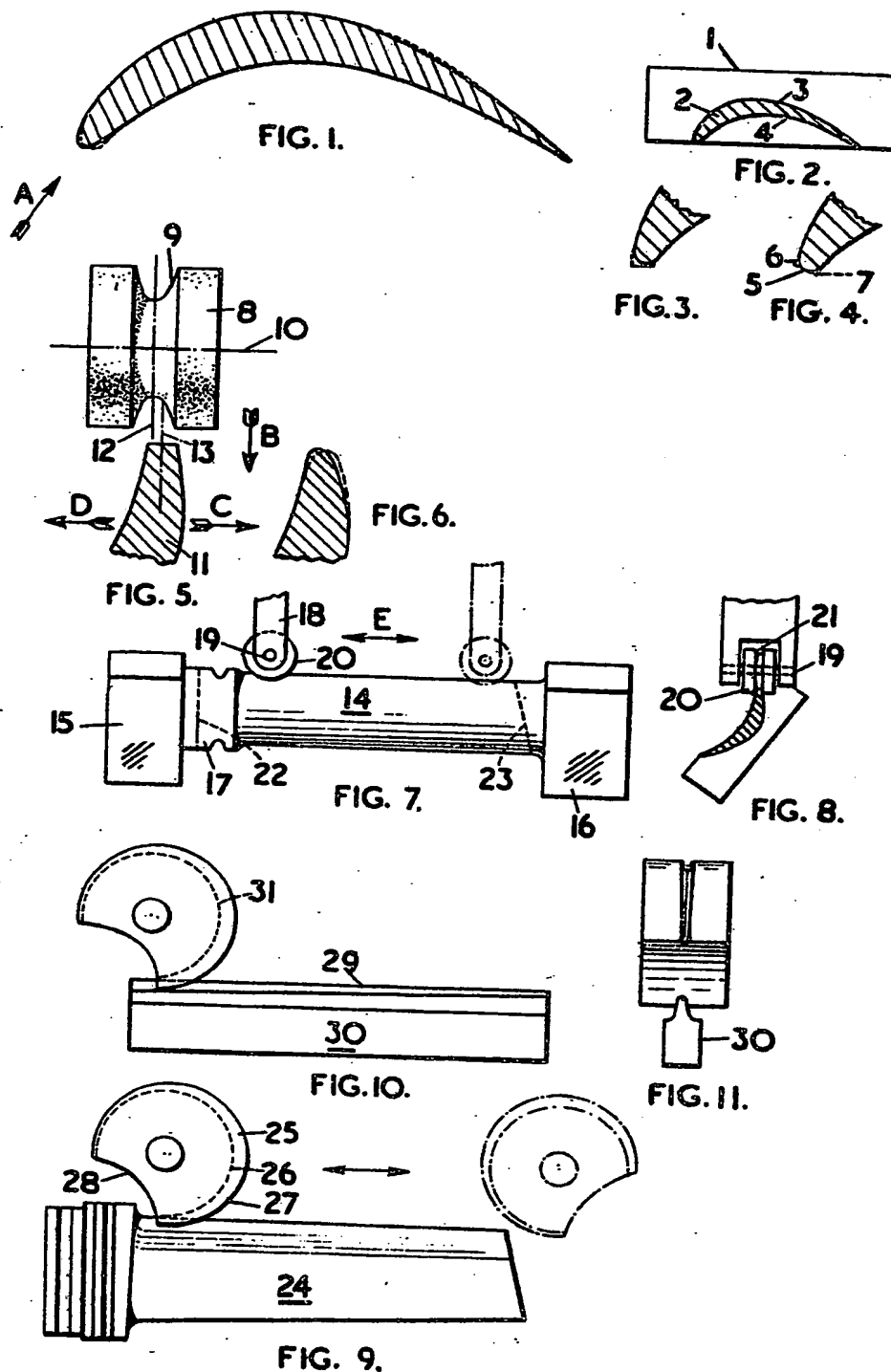
8. A blade of the kind referred to whose edges are formed by a method or apparatus according to any one of the preceding claims.

Dated this 28th day of September, 1949.

J. R. TOD,
Chartered Patent Agent,
Agent for Applicants.

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